DESIGN & HANDLING OF HIGH ACTIVITY COLLIMATORS & RING COMPONENTS ON THE SNS*

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Abstract

The Spallation Neutron Source (SNS) accelerator systems will provide a 1GeV, 1.44MW proton beam to a liquid mercury target for pulsed neutron production. The expected highest doses to components are in the collimator regions. This paper presents the mechanical engineering design of a typical collimator highlighting the design features incorporated to assist with removal once it is activated. These features include shielding and lifting fixtures but more importantly a double contained flexible water system incorporating remote water couplings. Also presented is a mechanism that allows axial movement of vacuum bellows and its associated vacuum clamps. Much design work is now focused on other areas of the storage ring and a status of this work is included.

INTRODUCTION

The collimators in the SNS accelerator were identified early in the design stage as areas that will become activated and therefore require careful mechanical design with respect to handling in the activated state. Several features have been included as the design has evolved such as integrated lifting, quick release water couplings, remote vacuum clamps and a mechanism for remote movement of the vacuum bellows. Other areas of the accelerator ring are now being addressed and work has concentrated on a co-axial bellows arrangement that facilitates simple remote axial movement. This is required in the dump regions and more specifically at the interface of the ring to target beam transport (RTBT) and the target flight tube. Design work continues at this interface region with the need to address the expected high prompt and residual dose levels.

COLLIMATOR MECHANICAL DESIGN

The collimators are distributed around the ring lattice as shown in Figure 1, with two in the high-energy beam transport (HEBT) line, three in the ring collimation straight and two in the RTBT line. The ring collimation straight [1] incorporates a beam scraper and primary collimator with two tertiary collimators. Halo particles that are intercepted by the scrapers will be either deflected directly to the primary collimator or into one of the other two collimators immediately downstream. The basic design of the collimator [2] comprises a double walled co-axial Inconel-718 vacuum vessel surrounded by a water-cooled bed of stainless steel balls. The gap between the co-axial tubes is maintained by the addition of a copper strip wound in a helix around the outer diameter of the inner tube; this inter-space is filled with pressurized helium to enhance the heat transfer. This configuration eliminates the possibility of water leaks into the vacuum and if the inner vessel wall is breached the helium will be detected in the vacuum system. The collimators will be water cooled from a dedicated closed loop cooling skid incorporating features such as double contained pipe-work, shielded resin beds, pressurized back flush, etc. The cooling water will be fed to the collimators via double contained stainless steel flexible hoses with quick release water couplings. The double contained distribution system has been designed to eliminate the chance of an activated water leak spreading from the collimator containment.

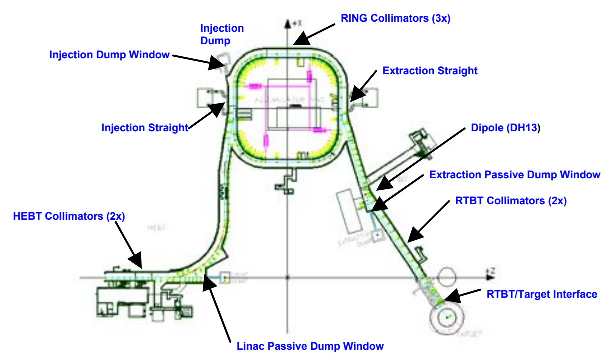

Figure 1: SNS Ring Lattice Showing Collimators

COLLIMATOR HANDLING FEATURES

Several design features have been utilized to minimize the dose level to personnel during change out of an active collimator. Three distinctive areas have been addressed, namely, access and lifting of the collimator, design of the water system and design of a mechanism to move the vacuum bellows on adjacent components.

Figure 2 shows the final design of a typical collimator in this case from the HEBT line. The collimator is shown with the outer shielding removed; this shielding can be lifted in one operation with minimal hands-on involvement. Once the outer shield is removed the collimator is exposed with the integrated lifting fixture mounted on top. The lifting fixture design allows the accelerator ring two-hook crane to engage on each end of the collimator, with the operator a suitable distance from the area. Once the water and vacuum connections are separated the collimator can be lifted directly out of the permanent shielding and transported to suitable area.

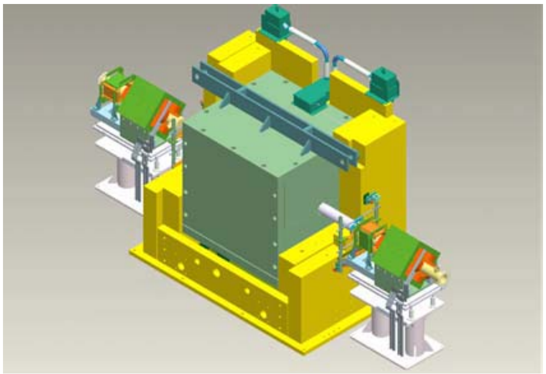

Figure 2: HEBT Collimator Assembly

The water feed system that connects the collimator to the cooling skids is designed to a specification similar to that of the cooling skids themselves. The cooling water flow and return pipes exit the collimator on the top face. A double contained co-axial flexible piping system is designed to attach to these pipes and to route any potential leaks back through the outer sheath and into the skid header tank. Figure 3 shows the installed assembly.

Figure 3: Double Contained Co-Axial Piping System

At the end of each flexible arm is a quick release water coupling that is based on an existing proven design [3] and has been modified to suit the collimator geometry. Figure 4 shows the installed coupling.

Figure 4: Quick Release Water Coupling

The coupling incorporates a bayonet end that retains an annealed copper disc. A water tight seal is obtained by compressing the copper seal between the bayonet and the body of the fitting, both of which have grooved seal faces. Load is applied to the bayonet by positioning the bail over the bayonet and applying torque to the bail screw. The co-axial stainless steel bellows are flexible enough to allow the bayonet to be removed using long handled tongs after the bail has been released.

Collimator removal requires not only disconnection of the water couplings but also separation from its adjacent components, consequently the vacuum clamps must be taken off and the vacuum bellows of the upstream and downstream components retracted to create enough clearance to allow the collimator to be safely lifted. The upstream end of the collimator is expected to be the highest dose area consequently a bellows mechanism and vacuum clamp [4] have been designed to permit remote disconnection.

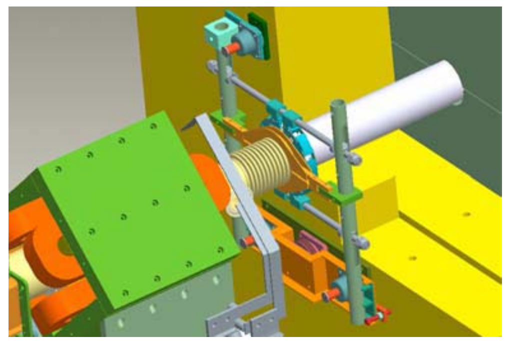

Figure 5: Extraction Mechanism Attached to Collimator

Figure 5 shows the design of the clamp and bellows mechanism assembly in situ. The assembly is bolted to the side of the collimator permanent shielding and attaches to the adjacent vacuum bellows via a clamping ring, the positional relationship between vacuum clamp and bellows clamping ring is maintained by both components being mounted off the same framework, see Figure 6. Movement is obtained by pressurizing a captive bellows and in turn the assembly slides on three die posts.

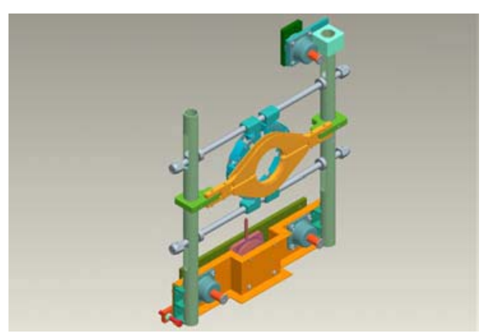

Figure 6: Bellows & Clamp Extraction Mechanism

RTBT/TARGET INTERFACE

Design work is now focusing on the RTBT/Target interface; Figure 7 shows a 3-D model of this area. Prompt and residual dose levels are calculated to be very high which makes maintenance of these components once activated extremely difficult. The design philosophy is based on vertical access from above for active handling operations. The components at the end of the RTBT are assemblies designed to be radiation hard e.g. the large quadrupole magnet (Q29 & Q30) weigh ~25 Tons and each have mineral insulated coils. The magnets have integrated shielding above that will also serve as a support structure. The support structure will rest on a kinematic rail system. All electrical and water connections will be terminated above the integrated shielding to improve accessibility and limit dose.

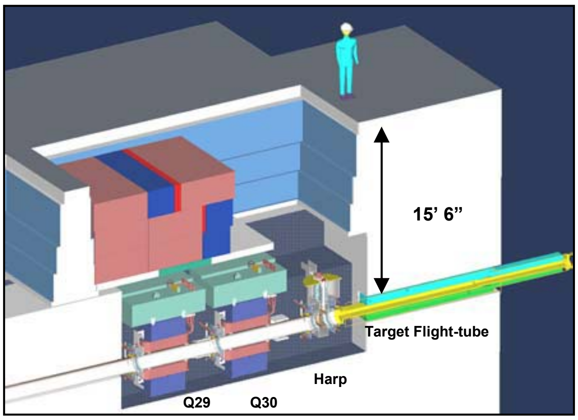

Figure 7: RTBT/Target Interface

A typical quadrupole magnet assembly is shown in Figure 8. These assemblies will utilize a larger version of the collimator vacuum clamp. A co-axial bellows arrangement has been designed and built for the linac dump and it is foreseen that a larger version of this design will be used in the RTBT area in conjunction with the large vacuum clamp.

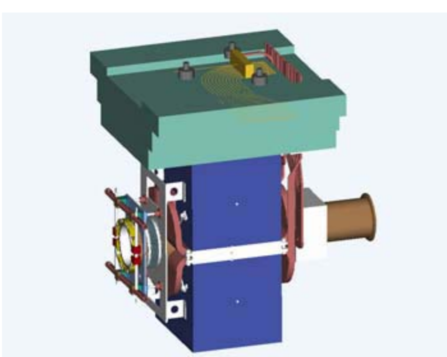

Figure 8: RTBT Quadrupole Magnet Assembly

The co-axial bellows and clamp assembly has been built and installed and validation is underway at the linac dump area of the ring. Helicoflex delta seals are used as they were found to require a lower sealing load per unit length. The bellows assembly comprises two concentric edge welded bellows one inside the other. Axial movement is achieved by either pressurization or evacuation of the inter-space depending on whether the assembly is manufactured naturally open or closed. Figure 9 shows the installed assembly at the linac dump.

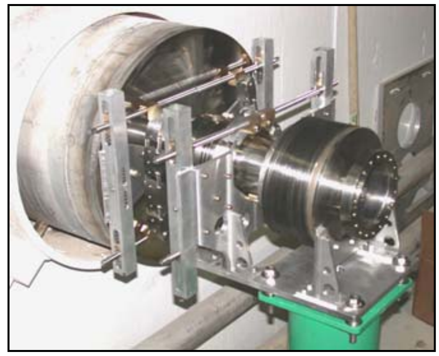

Figure 9: Co-Axial Bellows & Vacuum Clamp Assembly

The last component in the accelerator prior to the target flight-tube is the HARP diagnostic vessel that houses the HARP itself. The HARP is constructed of three planes of tungsten wires that are inserted into the proton beam to measure the horizontal, vertical and diagonal beam profiles. It is a requirement that the HARP is located with an accuracy of ±1mm. The weight of the HARP is ~32lbs and it is expected that it will require replacement approximately once every two years dependant on beam time usage. The conceptual design of the assembly is shown in Figure 10; it will also utilize the larger version of the collimator clamp and co-axial bellows.

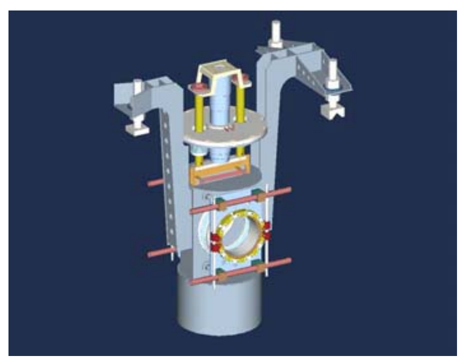

Figure 10: HARP Diagnostics Vacuum Vessel

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